Microcredit from Delayed Bill Payments

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Abstract

Delaying bill payments to public utilities may provide an important source of credit to households. With billing data from a water utility in Manila, Philippines, this paper builds a consumption and savings model to estimate demand for both water and credit. Estimates suggest that households value billing flexibility from the water utility as much as 7% of an average water bill. I then analyze the welfare effects of popular proposals to reduce delinquency by requiring upfront payments. Simulations find that upfront payments do not produce enough cost savings to justify their negative impacts on household consumption smoothing.

Keywords: credit constraints; consumption smoothing; water utilities.
JEL Codes: O13; E21; L95.

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What kind of flexibility, temporal?

A does this mean being able to not pay? under what terms?

A to whom?

"Recoup less revenue

1. Introduction

Households face a dynamic problem of how to smooth their consumption over time, especially in low-income settings where households have little access to formal credit and risky income streams (Morduch [1995]). Households often resort to costly money lenders or informal arrangements with family members (Banerjee and Duflo [2007]). Firms may provide an additional channel for consumption smoothing by allowing households to delay their payments for goods and services. In particular, public utilities often tolerate high levels of delinquent bills each month. Delinquent bills provide an economically important source of credit for households since public utilities cover broad populations and take up at least 5% of household incomes in developing countries.[1]

When market failures limit formal lending, public utilities may provide efficient, second-best sources of credit. First, poor access to collateral often restricts the availability of lending options to low-income households (Jack et al. [2016]). Public utilities overcome this barrier by threatening disconnection from future service to enforce repayment. Second, poor infrastructure and mobile populations increase the transaction costs of screening and monitoring debtors, which contribute to high interest rates (Jack and Suri [2014]). As part of their business practices, public utilities invest in meter reading and billing systems that may lower these transaction costs. Third, moneylenders and peer-to-peer lending groups often cater to small pools of debtors while public utilities are able to spread default risk across a wide customer base. Despite these advantages, linking credit to consumption from public utilities creates an inherent inefficiency by incentivizing overconsumption. For example, households may substitute toward piped water and away from other beverages in months where they are credit constrained. Since governments actively regulate public utilities, the extent to which public utilities should provide credit remains an open policy question (Laffont [2005]).

Technologies that eliminate delayed payments have recently dominated utility policy discussions. Both researchers and policymakers recommend new prepaid metering technologies, which require upfront payments before releasing any services, as effective strategies to prevent nonpayment.[2] Yet, existing analyses have yet to consider how these technologies may impact household welfare by reducing consumption smooth-

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[1]Komives et al. [2006] find that households spend 1-2% of their incomes on water and 4% on electricity.

[2]Kojima and Trimble [2016] and Heymans et al. [2014] point to prepaid metering as a successful strategy to reduce nonpayment for electricity and water utilities (respectively). Jack and Smith [2016] find that prepaid meters for electricity in South Africa substantially increase utility revenues.

ing.

This paper incorporates delayed payments to public utilities into household consumption and savings decisions in order to evaluate the welfare effects of offering credit through public utilities. I build a dynamic model where each period, households have the option of borrowing with a costly asset as well as with delayed payments to a public utility. Low interest rates on delayed payments induce households to increase their borrowing by overconsuming utility services. The extent to which households value payment flexibility depends on the borrowing costs of other assets, which are often difficult to measure in traditional survey data.

To estimate borrowing costs, I take a structural approach using billing data from a regulated water utility in Manila, Philippines. The identification strategy leverages months where utility workers visit households and disconnect them if they do not pay their outstanding balances. If borrowing were costless, households would never be disconnected during these visits because they would pay their outstanding balances with cheap loans. Therefore, long and frequent disconnections in response to these visits — especially among households with large outstanding balances — provide evidence of borrowing costs. Using this strategy, I estimate high interest rates for borrowing, consistent with poor observed access to formal credit in Manila with only 3.9% of households having credit cards and 18.7% having bank accounts.[3]

These estimates also allow me to simulate several counterfactual policies. First, I find that in a counterfactual where households are required to pay their bills on time (holding all else equal), consumer welfare drops by 50.3 PhP (or 1.1 USD) per household-month, which is equal to 7% of an average water bill. Usage also declines since households no longer have an incentive to overconsume water to fund their borrowing from delaying bill payments.

Second, I simulate a policy that (1) eliminates delayed payments by charging a high interest rate on unpaid bills, (2) eliminates default risk by preventing households from leaving large outstanding balances when they permanently disconnect, and (3) adjusts prices to ensure that the water utility remains revenue-neutral (consistent with regulation in Manila).[4] Without default risk, the utility has fewer costs to recover with prices. Yet without billing flexibility, households use less water, generating less revenue for the utility. On net, prices remain the same and the policy reduces social welfare by 51.1 PhP (or 1.1 USD) per household-month.

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[3]Statistics are from the Philippines 2014 Consumer Finance Survey.
[4]Laffont [2005] discusses economic reasons for these regulatory structures which are common in both developed and developing country settings.

Finally, I use this framework to evaluate implementing prepaid meters in this context. While ensuring that households pay upfront, prepaid meters require steep increases in prices to cover their installation and maintenance costs. As a result, prepaid meters produce large reductions in social welfare on the order of 225.2 PhP (or 5.0 USD) per household-month. Taken together, these results suggest that popular policies to reduce nonpayment may be welfare reducing primarily by limiting consumption smoothing. Given around 2.4 million piped water using households in Metro Manila, these policies would imply welfare costs on the order of 32.7 to 144.1 million US dollars per year.

This paper contributes to three main strands of economic literature. First, this paper brings payment and billing policy questions into a growing literature on optimal policy for utilities in developing countries (McRae [2015]; Szabó [2015]; Jack and Smith [2016]; Jack and Smith [2015]; Szabó and Ujhelyi [2015]). Building on previous static models, this paper also provides a framework for considering how dynamic incentives affect household demand for public utilities. Second, this paper draws on a large body of research analyzing household credit constraints, particularly through microfinance interventions (Morduch [1999]; Morduch [1995]; Cull et al. [2009]; Dupas and Robinson [2013b]; Jack et al. [2016]). Karlan and Zinman [2009] and Giné and Karlan [2014] specifically focus on microfinance in the Philippines. Third, Deaton [1991] provides the foundational model of dynamic decision-making that serves as the starting point for the model in this paper, and the estimation of this model adapts methods developed by Gourinchas and Parker [2002] and Laibson et al. [2007].

This paper proceeds with Section 2 describing the water billing data from Manila. Billing practices, disconnection policies, and institutional details are discussed in Section 3 alongside descriptive evidence. Section 5 develops a model of household consumption and savings decisions while Section 6 discusses the estimation and results. Counterfactual exercises and welfare impacts are provided in Section 7. Section 8 concludes.

2. Data

Measuring credit through delayed water bill payments requires information on water consumption and bill payments at the household-level as well as features of the credit environment in Manila.

Water consumption and bill payments come from water utility records collected as

3

part of a research partnership with one of the two regulated utilities in Metro Manila, Philippines where each utility is responsible for serving their assigned geographic half of Metro Manila. This utility provided access to monthly billing records for each connection as well as detailed information covering the regulatory structure and costs of production. Monthly billing records include meter readings, billing amount, outstanding balances, and payments spanning January, 2010 to May, 2015. Over this period, the total number of connections increased from 900,000 to 1,500,000 as the water utility expanded service access. Water connections are split into four categories: residential (90%), semi-business (4%), commercial (5%), and industrial (1%).

To focus on household decisions, the analysis includes only residential connections that are identified as serving a single household (31% of all connections), according to survey data on a random cross-section of 50,000 water connections between 2008 and 2012. Survey data also include demographics for households that own their water connections. Households using connections tend to be larger and wealthier than households that share connections with other households according to previous research (Violette [2019]). Table 8 in Appendix 9.1 includes more details on how the final sample is constructed for the analysis.

Since the analysis focuses on the borrowing and savings behavior of a representative household, additional data sources serve to characterize the borrowing and saving environment in Manila. Average household income is calculated using the 2015 Family Income and Expenditure Survey, which covers 4,130 households in Metro Manila. Interest rates for borrowing and saving come from the 2014 Consumer Finance Survey in Metro Manila as well as the World Bank Databank (2010-2015) for the Philippines.

3. Credit through Delayed Water Bill Payments

Delayed water bill payments may provide a reliable source of low-cost credit to households because (1) the utility tolerates high rates of delinquency before disconnecting water service and (2) the utility is prohibited from charging any interest on outstanding balances.

At the end of each month, the utility sends meter readers who record monthly consumption for each connection and then use a mobile device to print and deliver the bill to households in person. Households are then expected to pay the bill by the end of the month. Households have many options to pay their bills with 79% using small payment centers (mall kiosks, gas stations, convenience stores, etc.), 17% paying at local

utility offices, and 3% paying over phone, online, or via ATM kiosks.[5]

Despite easy payment mechanisms, households rarely pay their bills on time. Table 1 provides summary statistics on the usage, billing, and payment patterns of all households. On average, households are 56 days behind in their payments. Households also make large, infrequent payments. While the average bill is 671 PhP per month, payment sizes average 901 PhP and households make payments in only 71% of months. These payment patterns leave an average total outstanding balance of 1,206 PhP per month. For reference, 1 USD is worth around 45 PhP over this period.

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After bills have remained delinquent for over a month, the utility visits some delinquent households to disconnect their water service unless households immediately pay their bills, further referred to as a *delinquency visit*. Delinquency visits often surprise households. Likely due to time and travel costs, delinquency visits are relatively rare, occurring in only 1.9% of months where households are over a month delinquent. This rate ranges from 1.5% to 2.4% across the 12 business areas and is positively correlated with outstanding balances. Over the course of the sample, 30% of households ultimately receive delinquency visits.

Households respond to delinquency visits in three ways.

1) Following 72% of delinquency visits, households immediately pay their outstanding bills and avoid disconnection.

2) Following 8% of delinquency visits, households do not pay their outstanding bills, are disconnected within two months of the visit, and never reconnect during the sample period. I refer to these events as *permanent disconnections*. Disconnection typically involves placing a metal lock on the water meter that stops any flow. These households may have already planned to change dwellings, switch to a different water source, or leave Manila at the time that they receive a delinquency visit. Households that permanently disconnect often leave large outstanding balances that are never repaid averaging 7,119 PhP, which is over 10 times the average water bill. Since 0.13% of households permanently disconnect each month on average,[6] the average household remains connected for around 32 years assuming a constant rate over time.[7] Therefore, unpaid outstanding balances average 18.5 PhP per household-month or 2.8% of the

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[5]Statistics are calculated from the connection survey.

[6]The disconnection rate is calculated (1) for households that connect between 2007 and 2011 during the connection survey and (2) for disconnections occurring between 2012 and May, 2014 to ensure that any disconnections last for at least a year until the sample ends in June, 2015.

[7]This constant rate is consistent with a weak observed correlation between the permanent disconnection rate and calendar months of -0.0033.

average water bill.

3) Following 20% of delinquency visits, households do not pay their outstanding bills and are disconnected within two months of the visit; however, these households later pay their outstanding bills and reconnect during the sample period. I refer to these events as *temporary disconnections*. While households often try to negotiate for additional time to pay their outstanding balances, 96% of households are required to pay within 30 days and the average grace period is 13 days. As a result, only 25% of households report having "enough time" to make their payments. While temporarily disconnected, these households likely substitute to alternative water sources including sharing with neighbors, using from deepwells, or purchasing from local water vendors. On average, households wait 6.5 months before reconnecting. In order to reconnect, households must pay a small, one-time fee of 200 PhP on top of settling any outstanding balances. Households report being reconnected 2.3 days on average after full payment.

Among delinquency visits that occur when households are over three months overdue on their bills, 27.2% result in temporary disconnections and these households wait 7.5 months on average before reconnecting. By contrast, when households are under three months overdue, only 10.2% result in temporary disconnections and these households wait 4.6 months on average before reconnecting. This pattern is consistent with households facing credit constraints. When households are confronted with small debts to keep water service, they quickly pay to remain connected to service. Yet, when households must pay large debts to keep water service, many households delay payment for many months while they save income. This pattern suggests that households do not have access to low-cost credit, which would allow them to maintain water service.

4. Descriptive Evidence of Consumption Smoothing

If households are able to smooth consumption through borrowing and saving, then temporary fluctuations in income should affect borrowing and saving, but not consumption(Deaton [1991]). I test this theory with water consumption and water bill payments according to the following equation

$$\Delta Y_{bq} = \beta \, \Delta \text{INCOME}_{bq} + \gamma_q + \varepsilon_{bq}$$

Table 1. Mean Characteristics

	Mean	Std. Dev.	Min	25th	75th	Max
Usage (m3)	24.3	15.4	0.0	14.0	31.0	200.0
Bill	671	734	-4,640	265	843	19,999
Unpaid Balance	1,206	3,316	-9,965	0	1,044	79,904
Share of Months with Payment	0.71	0.45	0.00	0.00	1.00	1.00
Payment Size	901	1,067	0	313	1,070	49,688
Days Delinquent	56.2	113.7	0.0	0.0	61.0	750.0
Delinquency Visits per HH	0.40	0.70	0.00	0.00	1.00	6.00
Share of Months Disconnected	0.04	0.18	0.00	0.00	0.00	1.00

45 PhP ~ 1 USD   Std. Dev. refers to standard deviation. 25th and 75th refer to percentiles. Bills, Unpaid Balances, and Payment Sizes are in PhP per household-month. Negative bills and balances generally arise from refunds for billing or payment errors. See Appendix 9.1 for more details on the sample construction.

where INCOME_{bq} is proxied by the quarterly change in average labor earnings from Quarterly Labor Force Surveys where q indexes 28 quarters from 2009 to 2015. Average earnings are computed for 80 unique bins, b, defined by combinations of sub-municipalities (4), age in 5 year intervals (10), and whether college educated (2) in order to merge individuals from the Labor Force Survey to individuals water connection owners from the water connection survey. ΔY_{bq} is the quarterly change in either average water consumption (measured by the water bill in PhP) or average water bill payments (in PhP) by bin. Standard errors are clustered at the bin level.

Table 2. Correlations of Income with Usage and Payment Patterns

	(1) Δ Consumption	(2) Δ Payment
Δ Income	0.0007	0.0042[a]
	(0.0011)	(0.0013)
Mean	651	640
R^2	0.451	0.154
N	1,516	1,516

All units are in PhP. Quarterly fixed effects are included. Standard errors are clustered by age-group, sub-municipality, and whether college educated (80 units). [c] $p<0.10$,[b] $p<0.05$,[a] $p<0.01$

Column (1) of Table 2 finds a positive but statistically insignificant correlation between income and consumption. Due to measurement error in income, the small point

estimate of 0.0007 is likely to underestimate this correlation. Measurement error in income is probable both because only around 55 incomes are observed per quarter-bin in the Labor Force Survey and because bins are constructed from coarse demographic categories that may only loosely reflect household incomes. Despite this potential measurement error, Column (2) of Table 2 finds a statistically significant correlation between bill payments and income that is six times larger than the correlation between income and consumption.

These results provide suggestive evidence of consumption smoothing where households flexibly adjust their payment patterns in response to income shocks while maintaining the same levels of water consumption. This interpretation relies on the assumption that labor market shocks are uncorrelated with consumption and payment patterns except through their effects on household income. To overcome limitations in identification and measurement, I specify a structural model of consumption smoothing in Section 5 to assess the extent to which households delay bill payments as a source of credit.

5. A Model of Borrowing, Saving, and Water Use

To quantify the implications of different billing policies for household welfare, I construct a simple model of household borrowing, saving, and water consumption decisions over time. This approach follows from the standard intertemporal utility maximization problem developed by Deaton [1991].

In this model, households first move to Manila in month 1 and then choose how much to borrow and save as well as how much water and other goods to consume each month until they leave the city in month T. Household expected utility in each month t is given by the following equation

$$E_t \Big[\sum_{\tau=t}^{T} (1 + \delta)^{t-\tau} u(w_\tau, x_\tau) \Big] \tag{1}$$

where utility is expressed as an increasing and concave function of monthly water usage, w_t, and consumption of all other goods, which are collapsed into a single bundle, x_t. Households have a rate of time preference $\delta \in (0, 1)$. In each period, households face a budget constraint as follows

$$x_t + p(w_t)w_t = y_t - D_{t+1}f + S_t - S_{t+1} \tag{2}$$

8

where $p(w_t)$ captures the price per unit of water and may fluctuate with water use according to the water tariff structure.[8] The price of other goods, x_t, is normalized to one. y_t represents household income each period which takes a value of $(1 + \theta)\bar{y}$ with probability $\pi \in (0, 1)$ and a value of $(1 - \theta)\bar{y}$ with probability $(1 - \pi)$ where $\theta \in (0, 1)$. At the beginning of each period, households can choose whether to be temporarily disconnected ($D_{t+1} = 1$) or connected ($D_{t+1} = 0$) to water service. If households disconnect (or remain disconnected), they pay a fixed cost f. Since temporarily disconnected households are likely to share with neighbors or purchase from local vendors who re-sell piped water, they are assumed to face the same price per unit, $p(w_t)$, as connected households. Temporary disconnection allows households to delay paying their outstanding water balances, especially after receiving a delinquency visit, as described in more detail below.

By delaying payment of water bills, households are able to borrow against their future income realizations. S_t captures total assets chosen in the previous period to be consumed in period t while S_{t+1} captures total assets set aside in period t for consumption in $t + 1$

$$S_t = A_t + B_t \tag{3}$$

$$S_{t+1} = \frac{A_{t+1}}{1 + r_t^a} + I_t \frac{B_{t+1}}{1 + r_t^b} \tag{4}$$

A_t captures standard assets for borrowing and saving. The real interest rate r_a is assumed to take a value of r_l when households are saving ($A_{t+1} \leq 0$) and a value of r_h when households are borrowing ($A_{t+1} > 0$). This wedge in interest rates is intended to capture an institutional context with underdeveloped financial markets where households face high borrowing costs from moneylenders as well as high transaction costs in loaning out their own savings. This assumption is consistent with a recent literature in development economics that emphasizes how households often face savings and borrowing constraints.[9] Households are assumed to be unconstrained in their amount of borrowing or saving with this asset.

B_t captures borrowing through unpaid water bills. Households face a real interest rate r_b for borrowing from water bills. To prevent arbitrage cases where households borrow infinitely from water bills to invest in standard assets, r_b is assumed to equal

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[8]For example, Manila has a steeply increasing price schedule with monthly usage, which is described in more detail in Appendix 9.4.

[9]In Kenya, Dupas and Robinson [2013b] and Dupas and Robinson [2013a] estimate large willingness-to-pay for improved savings technologies. In Manila, Karlan and Zinman [2009] find high interest rates for loans from moneylenders.

r_h when households are saving through standard assets ($A_t > 0$), and is equal to r_w otherwise. r_w is equal to zero in the context of Manila since the utility is not allowed to charge interest on outstanding balances.

I_t is an indicator that determines when households are able to borrow from their unpaid water bills and takes the following form

$$I_t = D_{t+1} + (1 - c_t)(1 - D_t)(1 - D_{t+1}) \tag{5}$$

where c_t is an indicator for whether a household receives a delinquency visit, which occurs with probability $\lambda \in (0, 1)$ in each period. If households receive a delinquency visit ($c_t = 1$) and they choose to remain connected ($D_{t+1} = 0$), then they must pay their full outstanding balance to remain connected, which means that households cannot continue borrowing against their unpaid water bill this period meaning that $I_t = 0$. Similarly, if currently disconnected households ($D_t = 1$) want to reconnect ($D_{t+1} = 0$), then they also need to pay their full outstanding balance this period meaning that $I_t = 0$. Choosing to disconnect ($D_{t+1} = 1$) allows households to avoid paying their unpaid balances until they choose to reconnect, meaning that $I_t = 0$ in the current period.

Given that households are able to borrow, the amount that they can borrow through unpaid bills is constrained as follows

$$B_t - p(w_t)w_t(1 - D_{t+1})(1 + r_b) \leq B_{t+1} \leq 0 \tag{6}$$

By leaving bills unpaid, households are able to borrow up to their outstanding balance inherited from last period, B_t, plus their total bill from water consumption this period, $p(w_t)w_t$, given that they remain connected to water service ($D_{t+1} = 0$). If households choose to disconnect ($D_{t+1} = 1$), then they can keep borrowing up to their existing outstanding balance, B_t, but they cannot add to this balance through unpaid water use. To capture the empirical fact that water bills are almost never overpaid, households are assumed to be unable to save with this asset.

This framework results in four possible states depending on whether income, y_t, is high or low and whether households receive a delinquency visit given by the indicator variable, c_t. Assuming that the probabilities of reaching each state are uncorrelated with each other yields the following transition matrix between states

How do you know when a HH is saving through water? Also think about paper presentation at conference

A but only if they get visited? clarify this!!

10

$$T_{t,t+1} = \begin{array}{c} (1+\theta)\bar{y}, \text{ no visit} \\ (1-\theta)\bar{y}, \text{ no visit} \\ (1+\theta)\bar{y}, \text{ visit} \\ (1-\theta)\bar{y}, \text{ visit} \end{array} \begin{pmatrix} \overset{(1+\theta)\bar{y},\text{ no visit}}{\pi(1-\lambda)} & \overset{(1-\theta)\bar{y},\text{ no visit}}{(1-\pi)(1-\lambda)} & \overset{(1+\theta)\bar{y},\text{ visit}}{\pi\lambda} & \overset{(1-\theta)\bar{y},\text{ visit}}{(1-\pi)\lambda} \\ \pi(1-\lambda) & (1-\pi)(1-\lambda) & \pi\lambda & (1-\pi)\lambda \\ \pi(1-\lambda) & (1-\pi)(1-\lambda) & \pi\lambda & (1-\pi)\lambda \\ \pi(1-\lambda) & (1-\pi)(1-\lambda) & \pi\lambda & (1-\pi)\lambda \end{pmatrix}$$

(7)

Given these definitions, the household's problem can be reformulated using a recursive value function approach where the household solves for a function, $V(X_t, z_t)$, that maximizes both current utility and the expected continuation value given the household's current asset-levels and their disconnection status, which are captured by X_t, as well as the current state given by z_t in the following problem

$$V(X_t, z_t) = max_{x_t, w_t} \ u(x_t, w_t) + (1+\delta)^{-1} E\left[V(X_{t+1}|z_t) \big| z_{t+1}, T_{t,t+1}\right]$$

$$s.t.$$

$$x_t + p(w_t)w_t = y_t - D_{t+1}f + S_t - S_{t+1}$$

$$-p(w_t)w_t(1 - D_{t+1}) \le \frac{B_{t+1} - B_t}{(1 + r_b)} \le 0$$

(8)

$$X_t = [A_t, B_t, D_t]$$

$$z_t = [y_t, c_t]$$

This problem can be solved in two steps: (1) maximizing utility within a given period by choosing w_t and x_t holding assets fixed, and (2) choosing assets to maximize utility over time.

Within each period, households solve a standard utility maximization problem over water, w_t, and other goods, x_t, subject to a budget constraint determined by their current income as well as current and future assets, which are taken as given for this step. When given asset levels require borrowing through unpaid water bills, households face an additional constraint: they need to consume enough water this period to fund their water borrowing target. For example, households may drink tap water instead of soft drinks or other beverages in months where they are especially credit constrained. Formally, this situation occurs when equation (6) is binding.

To express these constraints formally, let $L = \frac{B_{t+1} - B_t}{1 + r_t^b}$ indicate the amount of revenue needed to be raised through water consumption to fund given borrowing targets. Likewise, let $Y = y_t - D_{t+1}f + A_t + B_t - \frac{A_{t+1}}{1+r_t^a} - I_t\frac{B_t}{1+r_t^b}$ equal all other net income used for consumption this period. Also, let utility take a Cobb-Douglas shape in water and all

11

other goods with preference parameter, $\alpha \in (0, 1)$. Cobb-Douglas preferences assume that households spend a constant share of their income on water and that the price-elasticity of demand for water is equal to one, which is in range with recent estimates in the literature.[10] The Cobb-Douglas utility function is also assumed to take a log-log form, which assumes that households have a moderate demand for smoothing income over time. Appendix 9.2 discusses this assumption in more detail.

The price of water is parameterized as a linear function of water use, $p(w) = p_1 + p_2 w$, to approximate the increasing block tariff present in Manila. Suppressing most time subscripts for ease of exposition, the household maximization problem takes the following form within each period

$$max_{w_t, x_t} \quad \alpha \, log(w) \, + \, (1 - \alpha) \, log(x)$$

$$s.t.$$

$$(p_1 + p_2 w) \, w + x = Y - L$$

$$(p_1 + p_2 w) \, w (1 - D_{t+1}) \leq L$$

(9)

Optimal consumption takes a piecewise form depending on whether households have to increase their water use to satisfy their demand for borrowing

$$w^* = \begin{cases} \frac{p_1 - \sqrt{p_1^2 - 8 L \alpha p_2 + 8 Y \alpha p_2 + 4 L \alpha^2 p_2 - 4 Y \alpha^2 p_2}}{2 p_2 (\alpha - 2)} & \text{if } L \geq \widehat{L} \\ -\frac{p_1 - \sqrt{p_1^2 - 4 L p_2}}{2 p_2} & \text{if } L < \widehat{L} \end{cases}$$

$$\widehat{L} = \frac{Y}{2 (\alpha - 1)} + \frac{\frac{Y p_2}{2} + \frac{p_1^2}{8} - \frac{p_1 \sqrt{p_1^2 - \alpha p_1^2 + 8 Y \alpha p_2}}{8 \sqrt{1 - \alpha}}}{p_2}$$

(10)

where $\widehat{L}$ captures the point at which revenue demanded for borrowing is exactly generated by the household's optimal consumption. When borrowing demand outpaces revenue from optimal consumption (ie. $L < \widehat{L}$), then households must deviate from their optimal unconstrained consumption choice and instead consume enough water to exactly satisfy borrowing demand.[11] This overconsumption captures a potentially important inefficiency associated with using unpaid water bills as a source of credit. Combining optimal consumption in equation (10) with the budget constraint in equation (2) as well as the utility function in equation (9) results in an indirect utility func-

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[10]Violette [2019] finds an average price elasticity of 0.84 in this setting while Szabó [2015] finds an average price elasticity of 0.98 in South Africa. Other studies find elasticities ranging from 0.01 to 0.81 (Diakité et al. [2009], Strand and Walker [2005]).

[11]Note that a greater negative L signals more borrowing.

tion as a function of prices, income, and assets. The full indirect utility function is given by equation (11) in Appendix 9.3.

Given indirect utility in each period and a discount rate that is assumed to be greater than the return on savings (so that households do not save infinitely), $\delta > r_l$, households solve for a stationary value function in (8) that maximizes utility by mapping any combination of asset levels in period t into optimal future asset levels in period $t + 1$.

6. Estimation and Results

The goal of the estimation strategy is to map variation in payment behavior, temporary disconnections, and monthly consumption into estimates of income variation, borrowing costs, and preferences for water. Since identification relies heavily on the household's behaviors in response to delinquency visits, the estimation sample is limited to "stayers" — households that experience delinquency visits but remain connected for the last six months of the sample as described in Section 3.

Table ?? of Appendix ?? includes detailed descriptive statistics for stayer households and Figure ?? provides the probability of receiving a delinquency visit conditional on the days delinquent in the previous month for stayers. Focusing on stayers may limit the generalizability of the results, especially given that stayers somewhat differ demographically from the population of households as shown in Table ??.

Table 3 describes parameters that are assumed or calibrated prior to estimation. The monthly savings interest rate is calibrated to the prevailing interest rate in the Philippines over this time period. The estimation assumes a monthly discount rate of 2%, which implies an annual discount rate of 26.8% and falls in the range of recent structural and experimental estimates.[12] Since this discount rate is assumed to exceed the savings interest rate, households are able to solve for a well-defined value function.

To measure prices, the non-linear tariff structure is approximated by a linear function of monthly usage as described in more detail in Appendix 9.4. This simplification allows for computational tractability within the dynamic model.[13] This approach also parallels average pricing models of consumer demand for utilities as suggested by Ito

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[12]Andreoni and Sprenger [2012] estimate rates between 25% and 35% in an experimental setting and confirm exponential discounting. Laibson et al. [2007] use a similar consumption-savings structural approach and recover a discount rate of around 15%. Gourinchas and Parker [2002] use a similar structural approach finding a lower discount rate of around 5%.

[13]Violette [2019] and Szabó [2015] carefully capture non-linear pricing incentives with static models, which are very computationally expensive.

i'm not great with models and i'm not familiar with how ppl write these papers. but i'm thinking it would be nice to have some intuition recap at the end. just a

[2014].

Without monthly household income data, the estimation includes average income in Manila as measured by the 2015 Family Income and Expenditure Survey. This method may overestimate average household income because the estimation excludes shared water connections, which tend to used by poorer households. At the same time, this approximation may underestimate household income to the extent that the Family Income and Expenditure Survey includes households that are unconnected to piped water and also tend to be significantly poorer.[14] Households are assumed to face equal probabilities of high and low income shocks in any particular month while the size of monthly income shocks are estimated. The last term needed for estimation is the risk of receiving a delinquency visit each month. The risk of delinquency visits is calculated for the sample of stayer households who are over 31 days delinquent on their bills.

Table 3. Calibrated and Assumed Parameters

Savings Interest Rate	r_l	9.5%	Philippines data from World Bank Databank (2010-2015)
Water Interest Rate	r_w	0%	The regulator prevents charging interest on unpaid bills
Discount Rate	δ	2%	Mean of structural estimates from literature[†]
Tariff	$(p_1 + p_2 w)$	$(17.5 + 0.3w)$	Estimated price by water usage (See Appendix 9.4 for details)
Mean Inc. (PhP)	$\bar{y}$	33,824	Family Income Expenditure Survey (2015) for Manila
High Inc. Risk	π	50%	Assumed to ensure symmetric income shocks
Visit Risk	λ	1.9%	% of months with a visit among stayers with >31 days overdue

All measures are monthly. Annual rates are converted to monthly rates as follows: Monthly Rate = $(1 + \text{Annual Rate})^{1/12} - 1$

[†] See Andreoni and Sprenger [2012], Laibson et al. [2007], and Gourinchas and Parker [2002] for structural δ estimates.

Given assumed and calibrated parameters from Table 3, the estimation strategy is able to recover parameters described in Table 4 using moments in the data. Due to computational limitations, the estimation recovers a single set of parameters that apply to a representative household, which limits the generalizability of the results to particular subpopulations.

Average consumption primarily identifies household water preferences. With Cobb-Douglas preferences, identification rests on the assumption that household price elasticity is equal to one so that the preference parameter, α, can be recovered mainly from the share of the household budget used on water.

Without data on monthly household income variation, the estimation strategy is designed to recover the magnitude of monthly income variation that rationalizes the

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[14]The 2010 Census of Population and Housing finds around 4 to 5% of households were unconnected to piped water (Violette [2019]).

i thought they had a 60 day grace period? that means that probability of visit is zero from 31 to 60 days, and some positive number

amount of unpaid water bills observed in the data. Under the structure of the model, greater income variation increases household demand for credit, which in turn increases the amount of unpaid water bills. This approach assumes that the only reason that households choose not to pay their water bills is to smooth their consumption over time. This assumption may not be valid in cases where households pay their bills infrequently because they face travel or other hassle costs in making each payment. As discussed in Section 3, households have a variety of payment options available to them including through local convenience stores, online, and over the phone, which suggests that any additional costs of making each payment may be small. The fixed cost of disconnecting and using from an alternative water source is recovered from the share of households that disconnect in response to a delinquency visit. Disconnecting allows households to avoid immediately paying their outstanding water balances. Therefore, high disconnection rates suggest low fixed costs of being disconnected.

The borrowing rate from standard assets is identified from differential disconnections rates in response to delinquency visits for households above and below 90 days overdue at the time of a visit. This identification strategy leverages the intuition that many households with large debts at the time of a visit would require large loans in order to remain connected. Therefore, high interest rates on these loans may especially drive these households to temporarily disconnect in response to a visit. This identification strategy requires the assumption that households above and below 90 days overdue at the time of a visit face equal fixed costs of remaining disconnected. For example, if more delinquent households have better outside options for water, then this approach would wrongfully attribute their high disconnection rates to high borrowing costs. Also for this approach to be valid, households must be unable to predict the exact timing of delinquency visits. While Appendix 10 provides some evidence that the timing of delinquency visits is correlated with demographics and payment behavior, delinquency visits are relatively rare events and only 36% of disconnected households reported receiving advanced warning from the utility.

15

D maybe they don't pay because low chance of being caught?

How is this separately identified from income shocks? I'm going to have higher balances if I don't care

Table 4. Parameters to be Estimated

Parameters		Main Identifying Moments
Water Preference	α	Mean Usage
Income Shock Magnitude	θ	Mean Outstanding Balance
Fixed Cost of being Disconnected	f	% Disconnected 1-4 months post visit
Borrowing Rate from Standard Assets	r_h	% Disconnected 1-4 months post visit given 90+ days overdue when visited

The estimation routine solves the household's problem in equation (8) through value function iteration over a grid of asset values. Households can choose from 10 values of the standard asset, A_{t+1}, evenly spaced across a mean zero normal distribution with a standard deviation of 10,000, a minimum of -13,352, and a maximum of 13,352. Households can also choose how much to borrow from unpaid water bills, B_{t+1}, over 11 values evenly spaced across a mean zero normal distribution truncated above at zero with a standard deviation of 3,800 and a minimum of -6,340. The additional choice of whether to stay connected each period, D_{t+1}, brings the total possible number of asset combinations to 220.

The estimation strategy uses a simulated method of moments approach, which chooses parameters to minimize the sum of squared distances between simulated and true moments, weighted by their average values in the data. To generate simulated moments, the estimator creates a random 2,000 month chain of states according to the transition matrix (equation (7)) and calculates the household's predicted asset and consumption choices across these states (assuming asset levels of zero to start).[15]

Table 5 provides the estimation results. The Cobb-Douglas preference for water consumption is estimated to be 0.024, which is consistent with households' observed budget share dedicated to water in Manila. The estimated income shock of 0.342 implies that household income either increases or decreases by 34.2% of its average with 50% probability each month. This estimate can also be interpreted as measuring the coefficient of variation (CV) of income and falls on the lower end of previous estimates in the literature.[16] Hannagan and Morduch [2015] use monthly financial diaries in the US to calculate CVs of 0.39 for average households and 0.55 for households below the poverty line. Using household surveys from Mexico, Amuedo-Dorantes and Pozo

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[15]See Laibson et al. [2007] and Gourinchas and Parker [2002] for similar approaches to estimation.

[16]The coefficient of variation (CV) measures the standard deviation of monthly household income divided by average household income (Hannagan and Morduch [2015]).

i'm completely ignorant here. how do you choose these distributions for the assets?

D what about ex-

[2011] calculate CVs between 0.29 and 0.46.

The estimation recovers a fixed cost of being disconnected of 150.0 PhP/month. Previous research uses a static, structural approach to estimate a long-term monthly fixed cost from using alternative water sources of 130 PhP/month (Violette [2019]). While these estimates fall in a similar range, this paper produces a larger estimate of the fixed-cost likely because sudden disconnections leave little time for households to invest in finding low-cost alternative sources for water. This estimate is also likely to capture the one-time 200 PhP fee charged to households for reconnection.

The borrowing rate from standard assets is estimated to be 2.2% per month, which implies an annual interest rate of 29.8%. This estimate is substantially lower than the 20% per month interest rate that Karlan and Zinman [2009] document as being commonly charged by moneylenders in Manila. Despite this high interest rate, Karlan and Zinman [2009] document that at least 30% of their sample of microentrepreneurs report taking credit from moneylenders. The estimated borrowing rate of 2.2% is more similar to microloans of 1,000 PhP at 2.5% monthly interest offered to rural Filipino households as part of a microfinance experiment conducted by Giné and Karlan [2014].[17]

Table 5. Estimates

Parameters		Estimates
Water Preference	α	0.024 (0.00075)
Income Shock Magnitude	θ	0.342 (0.0318)
Fixed Cost of being Disconnected (PhP)	f	150.0 (34.3202)
Borrowing Rate from Standard Assets	r_h	0.022 (0.0055)
Households		33,490
Household-Months		2,073,884

Standard errors in parentheses are bootstrapped at the household-level.

Table 6 provides both moments in the data used for estimation as well as other moments to help understand the fit of the model. While the model is able to almost exactly match average usage and outstanding balance, the model has more difficulty matching

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[17]The annual interest rate of 29.8% well exceeds the average 13 to 25% range offered by microfinance providers worldwide surveyed by Cull et al. [2009]. Two possible reasons for this discrepancy are that (1) institutional reasons unique to Manila may limit lenders' abilities to offer low rates and (2) subsidies may allow many microfinance providers to offer below-market interest rates.

the slow decline in disconnection rates observed after delinquency visits. The model instead predicts that households who disconnect in response to a delinquency visit will quickly reconnect over the following four months. One explanation for this discrepancy may be that the distribution of income shocks does not allow for serial correlation so that households are assumed to quickly recover from negative shocks in the model. In reality, households may be temporarily disconnecting in response to longer-term negative income shocks like job-loss or illness. A similar pattern exists for disconnection conditional on being at least 90 days overdue when visited.

Table 6. Model Fit

Moments	Data	Predicted
Used in Estimation		
Mean Usage (m3)	26.20	26.58
Mean Outstanding Balance (PhP)	2415.8	2450.0
% Disconnected Post-Visit		
1 month	0.13	0.12
2 months	0.14	0.10
3 months	0.12	0.06
4 months	0.10	0.05
% Disconnected Post-Visit		
given 90+ days overdue when visited		
1 month	0.30	0.28
2 months	0.32	0.23
3 months	0.26	0.13
4 months	0.23	0.11
Unused in Estimation		
SD Usage	12.3	2.1
SD Outstanding Balance	3588.7	3165.0
Corr. Usage and Out. Bal.	0.31	0.00

"SD" stands for standard deviation and "Corr." stands for correlation.
"Out. Bal." stands for outstanding balance. Standard deviations in the data
are calculated with variation within households.

The model has difficultly matching moments that were not used in the estimation. Since log-utility encourages households to smooth their consumption over time, this model predicts very little variation in water usage over time. By contrast, high observed variation in usage is likely driven by the fact that households face idiosyncratic shocks to their water demand each month as household members travel for work, other families come to visit, or Manila experiences a heat wave. A more complete model may include a term for indiosyncratic water shocks although it is unclear whether these shocks would substantively affect the model's predictions for income smoothing across time. While poorly matching variation in usage, the model is able to generate over half of the observed variation in outstanding balances.

The data find a positive correlation between usage and outstanding balances, which suggests that households may take on water debt to fund extra consumption in months where they face large, positive shocks to their water demand. In the model, positive income shocks reduce demand for water debt and increase demand for water. At the same time, negative income shocks reduce demand for water while increasing demand for water debt. On net, the model finds zero average correlation between outstanding balances and usage.

This is your hook for the intro, but also this could be normal substitution from soda, is water a normal good?

Could you recenter this

Figure 1. 100 Months of Simulated Data around
a Period of Disconnection
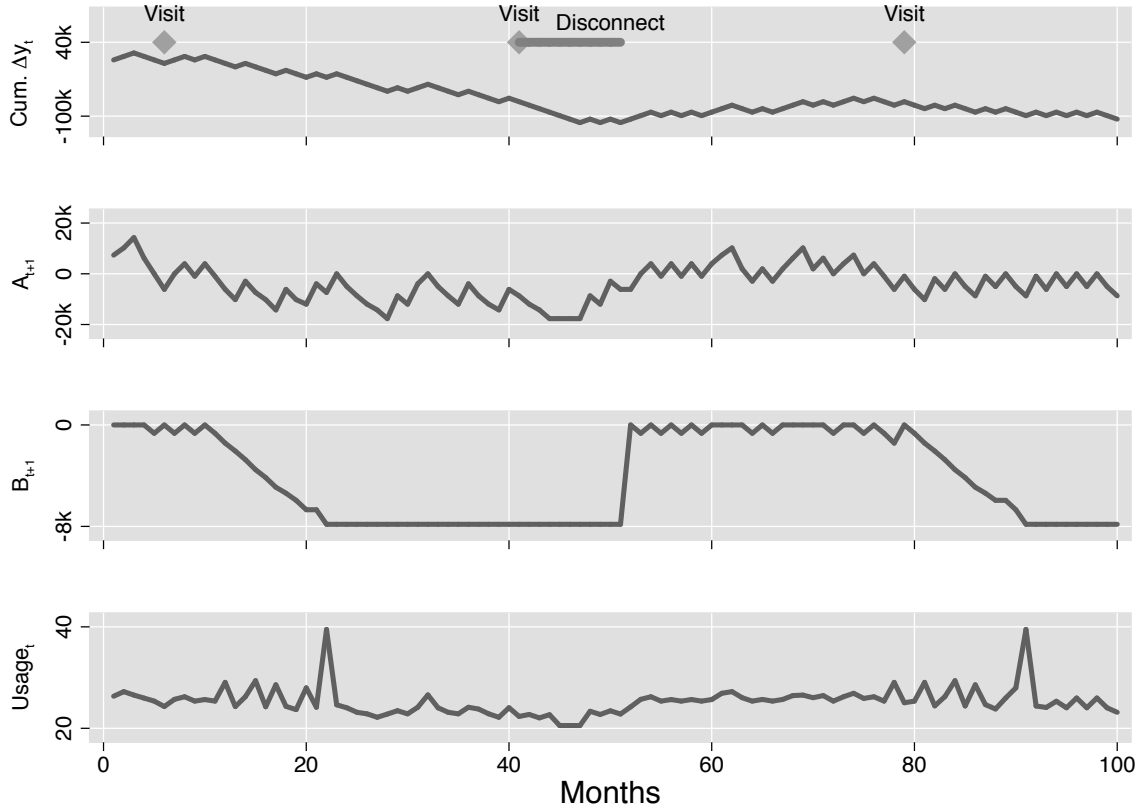
Note: 100 months are chosen to center around the first disconnection event in the 2,000 month random sequence of income and delinquency visit states used in the estimation. "Visit" indicates months with a delinquency visit with a diamond. "Disconnect" indicates months disconnected with a thick line. Cum. Δy_t measures cumulative shocks to income in PhP, A_{t+1} indicates the optimal position for standard assets in PhP, B_{t+1} indicates the optimal amount of water borrowing in PhP, and $Usage_t$ indicates water consumption in m3.

To build intuition, Figure 1 provides 100 time periods of simulated data from the model. These 100 time periods are chosen to center around the first disconnection occurrence in the 2,000 month random sequence of states used in the estimation. The first panel in Figure 1 indicates the cumulative, exogenous income shocks faced by the household. This sample begins with a long period where negative income shocks occur more frequently than positive income shocks. Positive shocks only begin to outweigh negative shocks at around 50 months. Indicators for when the household receives delinquency visits as well as whether it chooses to remain disconnected are also nested in this first panel. Over the course of 100 months, the household experiences three visits, the second of which leads the household to disconnect for around 12 months. This disconnection corresponds to a period where the household has accumulated a long string of negative income shocks.

20

The second panel indicates the household's choice of asset position, A_{t+1}, in each month. Asset position closely tracks income realizations as the household increasingly borrows (moving into very negative positions) following the long series of negative income shocks. At around the time of disconnection, the household chooses to borrow the maximum allowed by the grid of assets chosen for the simulation. Positive income shocks then allow the household to borrow less and begin saving at around 60 months.

The third panel indicates household borrowing through unpaid water bills, B_{t+1}. In the beginning, the household increases its borrowing more slowly than with standard assets since each month's increase in borrowing is limited by the size of the household's current water bill. Matching the downturn in income, the household continues borrowing before reaching the maximum borrowing allowed by the grid of assets chosen in this simulation. With few positive income shocks, the household remains at this maximum borrowing level for at least 24 months. When the second delinquency visit occurs at around 40 months, the household is still borrowing the maximum from unpaid water bills and therefore, instead of choosing to pay its full outstanding balance to stay connected, the household chooses to disconnect until it accumulates enough positive income shocks to pay its full water bill around month 55. During the third delinquency visit, the household's outstanding balance happens to be relatively small so it is able to immediately pay in full to remain connected.

The fourth panel indicates household water usage patterns over the same 100 months. Usage begins to spike as the household increases its usage to fund borrowing through unpaid water bills. The largest spikes in usage occur when the household moves to the maximum level of borrowing. Because of the step-size chosen for the asset grid, moving to the largest borrowing level requires a jump in unpaid bills of around 1,000 PhP. Since the average bill is around 600 PhP, the household needs to almost double its usage to fund this jump in borrowing from unpaid bills. These spikes in usage measure the extent to which borrowing from unpaid water bills may distort consumption choices, adding an additional friction associated with borrowing from water bills. After maximizing water borrowing at around 24 months, usage begins to stabilize at lower levels, mirroring the long string of negative income shocks faced by the household. Usage recovers to a higher level after the second delinquency visit before spiking again as the household maximizes its water debt in the last several months.

Why lumpy/spik

Why doesn't usage just go up smoothly?

If this is just a grid-size quirk, don't high-light

7. Counterfactual Policies

To measure how much households value credit from unpaid water bills, I examine how household welfare changes in a counterfactual setting where households are unable to borrow from their water bills. Table 7 includes outcomes for the current setting in Manila in Column (1) and for a counterfactual setting without water borrowing in Column (2), which is captured by raising the interest rate on unpaid water bills to 100% and holding all else equal. The first row calculates compensating variation equal to 50.3 PhP (or 1.1 USD) per household-month associated with losing access to water credit. This estimate suggests that households are indifferent between their current situation and a counterfactual with 50.3 PhP per month in additional income and without access to water credit. Given an average water bill of 671 PhP/month, this estimate would translate into households paying around 7% smaller bills each month.

Eliminating credit access also decreases mean usage by 6.0% as shown by columns (1) and (2) in the second row of Table 7. Eliminating credit access lowers the extent to which households can smooth their consumption over time while also removing the incentive for households to overconsume water in order to finance water borrowing. Given that households spend around 2.0% of their income on water, this estimate is roughly proportional to similar evidence from South Africa where restricting credit access with prepaid electricity meters produced a 13% reduction in usage and where households spend around 8-10% of their income on electricity (Jack and Smith [2016]).[18]

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[18]Jack and Smith [2016] also propose other mechanisms that may account for reductions in usage such as transaction costs and intra-household bargaining constraints.

Table 7. Counterfactual Policies

	Income Tercile	(1) Current	(2) No Water Borrowing	(3) Prepaid Metering
Compensating Variation (PhP)			-51.1	-225.2
	T1		-56.6	-230.3
	T2		-46.0	-235.1
	T3		-50.7	-210.2
Mean Usage (m3)		26.6	25.0	22.1
	T1	25.9	24.1	21.2
	T2	27.3	26.7	23.7
	T3	26.8	24.3	21.4
Price Intercept (PhP/m3)		17.16	17.19	22.86
Credit Supply Costs (PhP)		48.3	0	0
Marginal Cost (PhP/m3)		5	5	5
Additional Metering Cost (PhP)		0	0	51

All values are at the household-month level.

This setting also provides a useful opportunity to simulate the social welfare impacts of popular policies to reduce delinquency. I consider a policy that (1) eliminates borrowing by raising the interest rate on unpaid bills to 100% and (2) adjusts prices to ensure that the utility remains revenue-neutral. The regulatory structure in Manila as well as many other developing cities ensures that prices for water are regulated to exactly cover all production costs (Hoque and Wichelns [2013]).

Eliminating borrowing affects the costs of the utility in four main ways

1. *Opportunity Cost of Lending*: Currently, the utility faces an opportunity cost for the loans extended to households in the form of unpaid bills. Assuming that the utility would have been able to invest this money at an average annual interest rate of 9.5%, the opportunity cost of lending averages 41.5 PhP per household-month, which would be recouped by the utility in a counterfactual without delayed payments.[19]

2. *Delinquency Visit Cost*: Without water borrowing, the utility would no longer

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[19]Interest rate reflects the average between 2010 and 2015 as reported by the World Bank Databank.

need to conduct delinquency visits. Conversations with the utility suggest that travel costs make up the majority of the costs for any service performed on a water meter. Since the utility requires a 200 PhP fee to reconnect disconnected households, I assume that delinquency visits cost the same amount to the utility. Conditional on being delinquent, households receive visits in 1.9% of household-month observations, which implies an average delinquency visit cost to the utility of 2.5 PhP per household-month.

3. *Marginal Costs*: The utility reports a marginal cost per cubic meter of consumption equal to 5 PhP.

4. *Disconnection Rebate:* Currently, the utility is exposed to default risk where households that permanently disconnect from the utility often leave large outstanding balances that are never paid. On average, 0.0015 households permanently disconnect per household-month. These households that permanently disconnect leave average outstanding balances of 7,119 PhP. These estimates imply household savings equal to an average of 10.2 PhP per household-month. In practice, households enjoy all of these savings in the final few months that they remain connected. However, since households use water indefinitely in the model, the counterfactual exercise captures these savings by assuming that households receive a monthly fixed disconnection rebate of 10.2 PhP. By evenly spreading these savings over time, this approach is likely to overstate the true benefits to households from leaving unpaid bills. This approach relies on the following additional assumptions

- By assuming that households receive fixed rebates, this approach ignores any incentives that households may face to overconsume in their final months connected (since households may behave as if they face an effective price of zero in these months). Appendix 9.5 finds some evidence of overconsumption before permanent disconnection although the short duration and small magnitude of overconsumption suggest that excluding this margin will have little impact on total welfare estimates.

- Household decisions over when and whether to permanently disconnect from service are assumed to be unaffected by changes in billing flexibility. Since permanent disconnections are likely to be driven by households changing residences, this assumption is consistent with quality of water access having little effect on household location decisions.

How is this a cost? I'm confused by this section. Is this real or model assumption

24

- This approach assumes that under a counterfactual setting with a high borrowing interest rate, households always pay their bills on time even when they are about to permanently disconnect. This assumption may be reasonable since households would only have an incentive to delay their payments when they are close to permanently disconnecting. Since permanent disconnections are rare, the utility can credibly threaten to disconnect households as soon as they stop paying their bills. This threat would likely ensure that households always pay their bills on time.

To determine price increases necessary to cover these costs, the following expression first calculates the revenue raised through prices, p_1 and p_2, per household-month given income, Y, net of marginal cost, MC

$$REV(p_1, r_b, Y) = \left(p_1 - MC + p_2\, w^*(p_1, p_2, r_b, Y) \right)\, w^*(p_1, p_2, r_b, Y)$$

I then solve for the new price intercept, p_1', such that the current revenue is equal to revenue under a counterfactual where the borrowing rate is equal to 100% and the utility enjoys cost savings. This exercise assumes that the government regulator is able to perfectly forecast water demand among all households. Adjusting only the price intercept, p_1', instead of both price terms provides a way of preserving the slope of the tariff structure, which likely reflects equity concerns among policymakers in Manila.

p_1' is chosen to solve the following expression

$$\sum_t REV_t(p_1, 0, Y_t) = \sum_t REV_t(p_1', 1, Y_t - \text{Disc. Rebate})$$
$$- (\text{Opp. Cost of Lending} + \text{Visit Cost} + \text{Disc. Rebate})$$

In the counterfactual, cost savings reduce the amount of revenue needed to be raised to stay revenue neutral. At the same time, eliminating borrowing in the counterfactual lowers water consumption, which reduces revenue since prices are well above marginal costs. Table 7 finds that these two effects almost exactly offset each other, producing almost identical prices in the current setting in Column (1) and in the counterfactual without water borrowing in Column (3). Removing water borrowing while keeping similar prices results in a drop in average usage between Columns (1) and (3) that is nearly identical to the drop in usage between Columns (1) and (2).

According to the first row of Table 7, households would require a compensating monthly payment of at least 51.1 PhP in order to move from the current setting in

Column (1) to a revenue-neutral counterfactual without borrowing in Column (3). Although prices remain almost identical in Column (3), revenue neutrality ensures that households no longer receive a monthly disconnection rebate of 10.2 PhP, which almost exactly accounts for the difference in compensating variation between columns (2) and (3).

I then simulate the effects of introducing prepaid metering technologies and adjusting water prices to similarly account for their costs. By requiring households to pay upfront for their water usage, these meters provide an alternative strategy for eliminating unpaid water bills. These technologies have become increasingly popular for both electricity and water utilities throughout the developing world.[20] These technologies may be especially useful in contexts where other factors drive delinquency instead of consumption smoothing. For example, Szabó and Ujhelyi [2015] suggest that low levels of trust in local government and perceptions of fairness may drive some non-payment behavior. While these factors are not explicitly modeled in this context, this exercise may still provide a useful lower bound for evaluating the welfare effects of prepaid metering programs.

Prepaid meters introduce an additional cost for the utility in terms of purchasing and installing this new technology. Heymans et al. [2014] surveyed eight large water providers that implemented prepaid meters in developing countries and found that each prepaid meter costs about four times as much as a standard meter and requires replacement every 7 years. In the context of Manila, each standard meter costs around 1,500 PhP and is replaced around every 6 years and 3 months, bringing the monthly cost to 20 PhP/month.[21] Assuming that a prepaid meter costs 4 times as much as a standard meter with a replacement rate of 7 years, the estimated monthly cost of a prepaid meter would be 71 PhP/month. Therefore, prepaid meters imply an additional cost of 51 PhP/month per household.[22]

Column (4) of Table 7 includes the results of the prepaid metering counterfactual. To cover the much higher costs of prepaid meters, the price intercept, p_1, increases by around 33.2% as indicated by the fourth row. Households also no longer receive a disconnection rebate of 10.2 PhP per month. With higher prices and without water credit,

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[20]See Jack and Smith [2016] and Northeast Group [2014] for electricity utilities and Heymans et al. [2014] for water utilities.

[21]The utility provided additional documentation of their costs and frequency of meter replacement for residential households.

[22]Heymans et al. [2014] also report that the fixed administrative costs of installing and monitoring new meters account for less than 4% of the total costs of switching to prepaid meters while the bulk of the expenses come from purchasing new meters. By focusing on meter replacement, this exercise is likely to capture the majority of switching costs associated with prepaid metering.

26

does this constrain my water use? i can only use what i paid for? oh or is it like pre-paid cell phones and you just pay more when your balance is running ning

households lower their consumption by 17.0% under prepaid metering compared to the current setting in Column (1). In order to be indifferent between the current setting and a counterfactual with prepaid metering, households would need to receive 225.2 PhP/month in compensation. Taken together, these results provide suggestive evidence that prepaid metering would reduce welfare substantially in this context.

8. Conclusion

Prepaid meters for electricity already compose over 27.5% of residential meters in Sub-Saharan Africa and are predicted to grow to 52.8% by 2024 (Northeast Group [2014]). Similarly, by planning to install over 300,000 prepaid meters, the Botswana Water Utilities Corporation provides an example of the growing use of this technology in the water sector (Heymans et al. [2014]). Policy proposals for prepaid meters often emphasize how this technology ensures cost-recovery for utility providers. At the same time, households stress how "water is a need, but money is not always available" and how "postpaid gives you more time to find the money" in qualitative evidence documented by Heymans et al. [2014]. These anecdotes suggest a potentially important role for billing flexibility in allowing households to smooth consumption.

This paper builds a dynamic model of household consumption smoothing to measure the extent to which households value billing flexibility. Estimates imply that households' valuation of flexibility is on the order of 7% of their monthly water bills. Counterfactual exercises further find that policies to eliminate nonpayment — raising interest rates on unpaid bills and prepaid metering — do not produce enough cost savings to justify their negative impacts on household consumption smoothing. On net, these policies are predicted to reduce social welfare by between 1.1 and 5.0 USD per household-month.

In focusing on the role of consumption smoothing, this approach abstracts away from other channels by which nonpayment may affect welfare. First, high rates of nonpayment may weaken incentives for utilities to invest in and extend access to high quality infrastructure. While regulators in Manila successfully ensure universal access and service quality, McRae [2015] documents how electricity providers in Colombia often shirk on infrastructure investments in areas where they face high levels of nonpayment, which are also often underprivileged areas. Second, policing nonpayment through unexpected disconnections may also have unintended health consequences (Franklin and Kurtz [2017]). The US Department of Health and Human Services [2019] lists a series of state-level policies restricting disconnections, especially in months with

i'm still not sure i get this... what are the cost savings?

i would add more

extreme temperatures, for public health reasons. Finally, nonpayment may provide a way for households to voice their dissatisfaction with a utility as well as local government. Szabó and Ujhelyi [2015] find evidence that reaching out to consumers on behalf of a water utility increased payments from households motivated by a sense of reciprocity.

9. Appendix

9.1. Sample Construction

Merging the full sample from the connection survey to the billing data yields an initial population of 3,342,898 connection-months as described in Table 8. Non-residential accounts are first removed to ensure that results apply to household-level decisions. Due to some data inconsistencies, payment records are missing for some connections, which are excluded. Due to leaks, meter replacements, and meter reading errors, connections occasionally experience extremely high meter readings and bills. Consumption records above 200 m3 as well as bills and payments above 80,000 are censored to address these issues. Large negative payments and outstanding balances (due to reimbursements of billing errors) are also excluded due to likely measurement error. Remaining negative payments and balances likely represent refunds to households (possibly due to system errors), which are included to accurately reflect each household's asset position. Households that connect during the sample or have large stretches of missing records are excluded by including only connections with over 30 months of data. Keeping only connections serving single households brings the final sample size to 2,073,884 household-months.

Table 8. Sample Construction

	Observations	Observations Removed
Initial sample	3,342,898	
Keep residential connections (excluding commercial)		414,592
Keep connections with payment records		68,491
Keep months with usage under 200 m3		33,466
Keep bills > -5,000 PhP and < 80,000 PhP		51,537
Keep unpaid bills > -5,000 PhP and < 80,000 PhP		8,614
Keep payments > -80,000 PhP and < 80,000 PhP		0
Keep connections with over 30 months of records		0
Final sample	2,073,884	

9.2. Shape of the Utility Function

Log-utility is a special case of Constant Relative Risk Aversion (CRRA) utility given by $u(c) = \frac{c^{1-\rho}}{1-\rho}$ when $\rho = 1$. CRRA is one of the most popular functions for risk aversion in the economics literature (Wakker [2008]). The literature provides a range of estimates for ρ which are above, below, and around one. Barseghyan et al. [2013] use insurance choices in the US to estimate a ρ between 0.21 and 0.37. Beetsma and Schotman [2001] use a natural experiment from a Dutch game show to estimate ρ ranging from 0.42 to 6.99. Carvalho et al. [2016] leverage an experimental setting in Nepal to estimate ρ equal to 0.63. Given these estimates, assuming ρ equal to one implies a moderate curvature of the utility function and is relatively close to a comparable estimate from a development economics setting.

9.3. Indirect Utility Function

$$v^* = \begin{cases} \alpha \, \ln(\frac{p_1 - \sqrt{p_1{}^2 - 8\,L\,\alpha\,p_2 + 8\,Y\,\alpha\,p_2 + 4\,L\,\alpha^2\,p_2 - 4\,Y\,\alpha^2\,p_2}}{2\,p_2\,(\alpha - 2)}) - \\ \ln(\frac{(\alpha - 1)\,(8\,L - 8\,Y - 4\,L\,\alpha + 4\,Y\,\alpha)}{2\,(\alpha - 2)^2} + \\ \frac{(p_1\,\sqrt{p_1{}^2 - 8\,L\,\alpha\,p_2 + 8\,Y\,\alpha\,p_2 + 4\,L\,\alpha^2\,p_2 - 4\,Y\,\alpha^2\,p_2} - p_1{}^2)\,(\alpha - 1)}{2\,p_2\,(\alpha - 2)^2})\,(\alpha - 1) \\ \qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad \text{if } L \geq \widehat{L} \\ \alpha \, \ln\left(-\frac{p_1 - \sqrt{p_1{}^2 - 4\,L\,p_2}}{2\,p_2}\right) - \ln\,(Y)\,(\alpha - 1) \qquad\qquad \text{if } L < \widehat{L} \end{cases}$$

$$\widehat{L} = \frac{Y}{2\,(\alpha - 1)} + \frac{\frac{Y\,p_2}{2} + \frac{p_1{}^2}{8} - \frac{p_1\,\sqrt{p_1{}^2 - \alpha\,p_1{}^2 + 8\,Y\,\alpha\,p_2}}{8\,\sqrt{1-\alpha}}}{p_2}$$

$$(11)$$

9.4. Tariff Structure and Approximation

Table 9. Example Residential Tariff As Presented to Consumers

Usage (m3)	Price (PhP)
Under 10	104.73 /conn.
Over 10	181.00 /conn.
Next 10	19.17 /cu.m.
Next 20	25.48 /cu.m.
Next 20	33.92 /cu.m.
Next 20	40.66 /cu.m.
Next 20	45.92 /cu.m.
Next 50	50.14 /cu.m.
Next 50	55.31 /cu.m.
Over 200	57.63 /cu.m.

Mean tariff 2010-2015 with value added tax.
"conn." refers to connection.
"cu.m." refers to m3/month. 50 PhP~1 USD

Table 9 provides the monthly tariff structure as it is presented to consumers. Consumers face a fixed price as well as marginal prices for any usage above 10 m3. The regulator gradually adjusts prices at roughly yearly intervals in order to ensure that the utility is able to exactly cover its costs. The marginal price is highly non-linear, accelerating quickly at low usage levels before slowly increasing at high usage levels. To achieve a tractable approximation of this price schedule, Table 10 fits a simple regression model predicting average price as a function of an intercept, p_1, and monthly usage levels, p_2. This model predicts that a increase in monthly usage of 10 m3 results in an increase in average price of 2.2 PhP/m3.

Table 10. Average Price and Monthly Usage

	Avg. Price: $\frac{\text{Bill (PhP)}}{\text{Usage (m3)}}$
Usage (m3)	0.29[a]
	(0.00)
Intercept	17.48[a]
	(0.05)
Household-Months	1,931,849

[c] p<0.10, [b] p<0.05, [a] p<0.01

9.5. Usage Before Permanent Disconnection

Figure 2. Average Usage in Months Before Permanent Disconnection
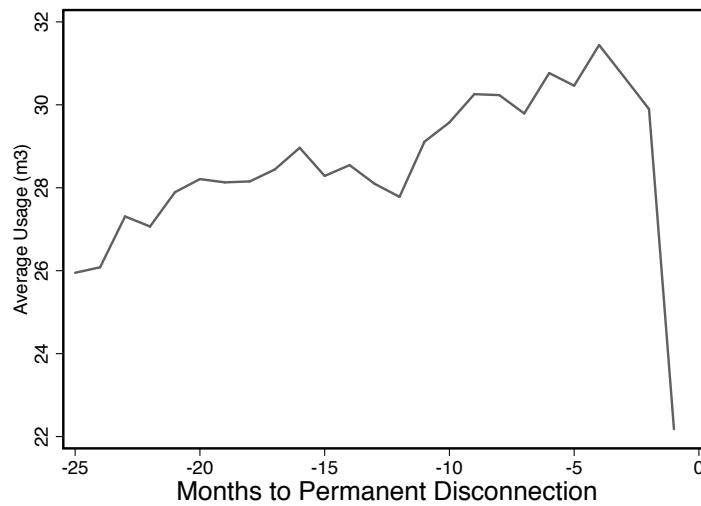
Permanent disconnection is defined as households disconnecting and remaining disconnected for the at least the last two years of the sample. Negative months indicate months leading up to permanent disconnection. Months with zero usage are dropped because households may leave months with zero consumption before the company disconnects them.

9.6. Income Coefficient of Variation

Table 11. Income Coefficient of Variation Estimates

	(1) Raw	(2) Adjusted
All	0.566	0.523
By Income Tercile		
T1	0.557	0.609
T2	0.552	0.474
T3	0.588	0.487
Demographic/Occupation Controls	No	Yes
Households	27,343	27,343
Years	2008, 2011	2008, 2011

The Coefficient of Variation (CV) for each household (HH) is $\frac{2|y_{2011} - y_{2008}|}{y_{2011} + y_{2008}}$ where y is HH income. Estimates take the mean CV across HHs. Income terciles are computed by mean HH income.
Adjusted CV is $\frac{2|\bar{y}_{2011} - \bar{y}_{2008}|}{y_{2011} + y_{2008}}$ where $\bar{y}$ is residual income controlling for HH employment by skill-level, oldest HH age, HH size by education, year, and HH fixed effects.

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